THE

CABLE RAILWAY SYSTEM.

THESIS

FOR

DEGREE OF B.S., IN SCHOOL OF MECHANICAL ENGINEERING.

BY
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Contents.

Part I.

Introduction.

Historical Outline of Wheeled Conveyances; and the Development of their use as Public Conveyances.

Before entering upon the discussion of a subject of this nature, one naturally inquires into its past progress: and, in this subject, it leads to the question — what and when were the first wheeled conveyanses introduced into history?

The origin of wheeled conveyanses is lost in antiquity. Two wheeled carriages in the form of chariots and wagons were known to be in use as long ago as 2000 years B. C. The Greek tradition that Erectorias, the fourth king of Athens, invented wheeled conveyances about 1400 B. C., is due to the "vanity of a nation who considered themselves _ne plus ultra_".

Joseph sent wagons to Canaan to fetch his father up into Egypt, which was about 1700 B.C. These were, no doubt, carts drawn by oxen; as horses at that time were not used for draft except on chariots.

The nations of China and India used carts from an early date which cannot now be determined. The modern Indian-cart is much like its predecessor.

The Romans, more advanced in civilization, used covered and cushioned carriages drawn by slaves or by horses; but in the city of Rome their use merely for pleasure was prohibited by law.

Though, as has been shown, wheeled conveyances have been in use since antiquity; their use as passenger conveyances to any extent is of comparatively recent date. Down to the sixteenth century kings, popes, ministers, and magistrates made their journeys on the backs of animals. During the fifteenth and sixteenth century covered carriages were used by women of rank: but it was considered disgraceful effeminacy for men to use them.

From this time on the use of vehicles as passenger conveyances steadily progressed, though the making of roads was necessary before their extensive use as such. The manufacture of coaches in England is dated from 1555. They were heavy, clumsy, and destitute of springs. The canopies of these coaches were supported by pillars on the bodies: and surrounded by curtains of cloth or leather which might be folded up when desired. The driver rode the near wheel-horse — a driver's seat being a luxury of a later date.

We have now seen vehicles as passenger conveyances established. The next step, and the one which leads to our subject, is their use as passenger conveyances for the public. Their use in this capacity dates from about 1625 — coaches at that time plying the streets of London for public hire.

Stage-coaches were introduced into England about 1650: and in a short time regular stage-coach lines were established which plied between the principal cities of every nation.

The problem of more rapid locomotion now began to be agitated. Rails were introduced and finally steam: and our great railroads of to-day are the result.

Although means of rapid locomotion had been attained, and has made rapid strides since 1829; yet this means of locomotion was only suitable for intercourse between distant points: there being little or no advancement in the means of passenger communication from point to point in our large cities. The coach and finally the omnibus still plied the streets of cities as the only means of public conveyance: and continued to do so until the street-car was introduced, which was not until 1850 in the U.S. and 1860 in England.

The street-car as first introduced, and as it is most extensively used now, was drawn by horses, the rails being laid in the middle of the street.

Though as means of public conveyance the street-car was introduced in 1850; yet nearly every article on the subject of street-cars claims that the idea was not original, being the same that was used in the English collieries nearly 300 years ago. It would be as sensible to go back to the time when the Romans paved the way for the wheels of their chariots to roll on or to the moving of the obelisks in Egypt. The idea is the same. The only difference being that then the track was made very wide so that the wheels would not run off; and now the wheels are made so that they will not run off the narrow track.

It would be more sensible to say that the street-car railroad is a modification of the general railroad, so as to be adapted to the requirements of city communication. This is what in reality, it is. Railroads in general have been developed from the idea of the tram-way system above mentioned; and that system in turn from still more ancient devices.

Having our street-railways established and the cars drawn by horses or mules, the next problem was a means of a more rapid as well as a safe communication through the streets other than by horses; and this problem is still under consideration. Numberless ideas have been brought forward; but few have gained much popularity.

Steam was the first substitute for horses; but it has never come into popular use as used directly. It has the advantage of fast locomotion as well as of economy. The engine is made noiseless by means of a special exhaust arrangement; and burns anthracite coal to prevent smoke. They have powerful brakes to keep them under control, stopping them in less time and space than horse cars; and it is stated that four steam motors will take the place of 63 horses and show a saving of about $40.00 per day; but notwithstanding its advantages, steam as used directly does not meet with much favor.

To do away with the objections to steam, the underground scheme has been tried. It has been in operation in London since 1863, when a section of three and a fourth miles was opened. In 1879 the length of such roads in London amounted to twenty miles. The main difficulty met with in its construction was the avoidance of the immense net work of sewer pipes.

An effort was made to construct an underground railroad in New York, and a portion of it was opened in 1870; but in consequence of mismanagement, engineering difficulties attending its construction, and the objection of property holders the scheme failed.

Rapid transit has been secured however in New York by means of Elevated Railways, which were first put into operation in 1877. There is however very great opposition to such roads by property holders along the street. In Chicago several attempts have been made for permission to introduce them; but have failed in consequence of the objections of property holders.

Many other substitutes for horses have been tried with more or less success. Among them are compressed-air-locomotives, fireless-locomotives or hot-water-engines, gas-engines, engines worked by the explosion of gun-cotton, elastic force of rubber, steel springs, <u>andc</u> <u>and c</u>; but none of them have come into popular use, with the exception of <u>The Cable Railway System</u>.

Part II.

General Description of the Cable Railway System and its Origin.

This system of street-car locomotion as in use is the invention of Mr. A. S. Hallidie of San Francisco; and was first put into operation in August 1873 — the trial trip being made the first day of Aug. Though the cable system as invented by Hallidie was the first to be put into successful operation; yet the U. S. Patent Office Records show that the idea of locomotion by means of an underground cable was not original with him. On examining these records we find a patent granted to G. S. Gardner of Phil. in 1858, in which he makes his claims as follows:
"I claim forming between the rails of a city railroad

track, an underground tunnel; and hanging a series of pulleys within the same, said tunnel having a longitudinal slot near the level of the ground, and being otherwise so arranged that a rope may be used for drawing the cars along the track without impeding the passage of vehicles across the same".

In all, there have been over 130 patents granted by the U. S. Patent Office on cable traction.

Notwithstanding the fact that the idea of locomotion by means of an underground cable was not original with Hallidie; yet it is owing to his perseverance and ingenuity that it has come into successful operation, and the public benefitted thereby. The conversion of these first roads from animal to cable traction was certainly a gigantic undertaking; and required more fortitude on the part of the projectors of the scheme than may be supposed; as there were many obstacles to be overcome, and considerable outlay to be made in experiments; and withal, an immense amount of capital was to be risked in order to put them into successful operation.

The idea of a moving cable is but the main idea, to put it into operation innumerable little difficulties have to be surmounted to secure its proper working; and these difficulties vary with every line of tunnel laid. It is owing to the surmounting of these little difficulties that Hallidie succeeded and for which he deserves credit.

The general description of the Cable System can be given in a few words; but the adapting of this system to any particular line, requires a great deal of intellectual labor.

The system consists of an endless wire rope, placed in a tube below the surface of the ground between the tracks of a railroad; and kept in position by means of sheaves, upon and beneath which the rope is kept in motion by means of a stationary engine at some point of the road. The power is transmitted from the motor to the rope by means of grip or other suitable pulleys; and from the rope to a grip-car or dummy on the street, by means of a gripping attachment fixed to the grip car and connected by a thin bar, which passes through a narrow slot in the upper side of the tube.

The system presents no impediment to ordinary travel. The rope is grasped and released at pleasure by the gripping device attached to the car and controlled by a man in charge. The car is more smoothly started than by horses and almost instantly stopped on any part of the road. Its mechanical construction is simple and easily controlled: and on the streets of a city it does not frighten horses and should not endanger lives. By this means of locomotion, no dead weight is needed to secure adhesion to the rails, the power of propelling not being in the wheels.

The tube is for the protection of the wire rope which runs inside, and the pulleys which support the rope, as well as for the protection of the gripping attachment or gripper which connects the rope with the car above. It also furnishes the bearings for the guide pulleys or sheaves, as well as a firm fastening for the slot. Change of direction in the line of rope is effected by means of small sheaves in sufficient number and placed in proper position to give the required curve to the rope.

In the plates at the end of this treatise may be seen drawings of various parts of Cable railways.

A fuller description will be given in describing the roads separately, or in the following account of the developement of the invention.

The Developement of the System.

We are indebted to the peculiar and inconvenient site of San Francisco for the developement of the Cable Railway System to practical use. The city is situated among steep hills — some of them having an inclination as great as one in six, and consequently almost inaccessable with a load. It was the problem of climbing these hills that developed the cable system. It was as much as five horses could do during the busy portion of the day to haul a car a distance of two blocks up grade, the ascent being 73 feet in 875 feet. In consequense of the difficulty in reaching the summits of these hills, property on them was of but little value before the introduction of the cable-system which is now high priced

Hallidie first determined to find some effective means of reaching the summits of these hills, while watching the horses struggling up one of them with a car.

His leisure time from his regular duties was spent in solving this problem; and in 1871 he confidentially laid his plans before a few of his friends. Some time previous to this he had California St. surveyed with the intention of running an experimental line up that street for a distance of 1,353 feet, in which distance there was a rise of 193 feet. The street was however abandoned and Clay St. selected instead. Ground was broken in June 1873 and the work pushed forward with vigor, the franchise requiring that the cars should run by the first of August.

The trial trip was made about four o'clock in the morning on the first day of August, a grey foggy morning, the ground being slippery with moisture. The engine was started and the rope, which was 7000 feet in length, moved through the tunnel beneath the street quietly and satisfactorily. The car containing the gripper was brought to the brow of the hill; and the gripper being lowered to the moving rope, the car was lowered over the brow of the hill a short distance by means of ropes, to see if the brakes were sufficient to stop the cars in case the gripper lost its hold. The brakes were found inadequate and consequently the prospect of running down the hill against time increased. A consultation was held and it was decided that the trip must be made. The man who was detailed to take the car down the hill not relishing the prospect, Hallidie took charge of the car, fastened the gripper to the rope; and with Messers Britton and Davis and six of the employees, started on their journey down hill. They reached the bottom in safety having tested the gripper in various ways during the trip — as stopping at the crossings, starting up, dropping the cable, picking it up, and c. The top of the hill was reached in safety and the first trip on the cable-railway was at an end. In the afternoon of the same day a trip was made with an extra car; and about sixty persons managed to crowd on and obtain a free ride.

The simplicity, regularity, and smoothness in the operation of the cable system are as much to be admired as the ingenuity and perseverance that overcame the many difficulties that presented themselves.

during its construction: and which we can appreciate only when we examine into the considerations and conditions connected with the first experiment. Many things had to be carefully weighed before entering upon a project in which a large amount of capital as well as the comfort and safety of citizens was at stake.

The ordinary traffic by wagons and carriages was not to be interfered with, and the surface of the street was required to be left free from obstacles of any kind. No posts or poles would be permitted in the streets nor would the authorities allow the use of any exposed motor that might frighten horses or explode. The cars were required to be under complete control, so that they could be stopped at any point in the route as quickly as with horses. The speed was limited to not less than three miles an hour or greater than eight miles: and the fare ~~was~~ not to exceed five cents for the entire trip.

To meet these requirements many difficulties presented themselves. The street was of an uneven grade and if a rope was used it had to be confined above as well as below, otherwise it would fly up in the air several feet above the surface at each crossing, where the rope changed suddenly from a level to a rise and to keep it down would necessitate a pulley above the rope and inside of the tube which would interfere with the gripper.

Another thing to be considered was the placing of the rope so as to protect it from the sand and grit, which would necessarily fall through the slot. The slot also must be too small to permit the narrowest carriage wheel to slip through. Many other minor points had also to be taken into consideration.

The gripper constitutes an important part in the success of the undertaking as also does the manner of braking the cars for on these two depend the safety as well as the efficiency of the cars.

One of the most important items of expense in the operation of a road of this kind, is the wear and tear on the steel rope. If it should break during the day it proves to be a matter of great expense. The average life of a rope on each road, with other data, is given in the tables in Part V.

Part III.

Outline of the San Francisco Cable Railways.

San Francisco has a number of cable roads now in operation. The use of them was at first confined to streets where the grades were very steep: but experience has shown them to be as applicable to level roads as to steep ones and now they are used on both.

Clay Street Hill Railway.

The Clay Street Hill Railway was the first cable road to be put into operation. The running of cars on it dates from August 1. 1873.

Clay street is a central street of the city and for a number of blocks near the lower terminus of the road is densely populated. The lower terminus of the road is at the the intersection of Clay St. with Kearney St.. The summit of the hill is 307 feet above Kearney St.. The incline on Clay St. has a double track and is 5,197. feet in length. The rope runs into the engine-house at Leavenworth St.. The ascending grades are as follows: (see profile of street grades fig. 1, Plate V) From Kearney to Dupont, 45 feet: from Dupont to Stockton, 45 feet: from Stockton to Powell, 62 feet: from Powell to Mason, 42 feet: from Mason to Taylor, 48 feet: from Taylor to Jones, 67 feet:— then the grade descends— from Jones to Leavenworth, 15 feet: Leavenworth to Hyde, 50 feet: Hyde to Larkin, 50 feet: Larkin to Polk, 45 feet: and finally there is an ascent of 15 feet between Polk and Van Ness Ave. The distance between each street is 412½ feet. The street crossings are level and the grades vary from 1 in 27½ to 1 in 6.3.

The general arrangement of the system, as used in Clay St. is as follows: An endless steel wire rope three inches in circumference and 11000 feet in length is stretched the whole distance, lying in iron tubes and supported every 39 feet by sheaves 11 inches in diameter. This rope is supported at every change of angle at the lower crossings on sheaves, four feet in diameter, and at the upper crossings is held down by a number of small sheaves arranged to give the proper curve. At the lower terminus of the line the rope passes around a sheave eight feet in diameter, which is mounted on a carriage and is horizontal. Attached to the fare end of this carriage is ~~attached~~ a chain which passes back and over a pulley into a well. In this well and attached to the other end of the chain, are weights sufficient to maintain the required tention on the rope. By means of this arrangement the tention on the rope is kept constant. At the upper terminus is another sheave eight feet in diameter, but its bearings are fixed.

At the engine-house the rope passed around two angle sheaves, each eight feet in diameter which lead it to the grip pulleys (see plates 12 and 13) The grip-pulleys are two in number and eight feet in diameter. The rope passes over the one directly connected with the engine, three times and over the other, twice. They are driven by one 14"x28" cylinder and the steam is furnished by one 16'x54" boiler, using 3700 lbs. of coal per day. There are also a duplicate engine and boiler which are held in reserve. The grip-pulleys have jaws at their circumference, which grip and release the rope automatically by means of the pressure in the jaws of the rope — thus preventing the rope from slipping.

The entire length of the tube in which the rope runs, has a slot in the upper side 3/4 of an inch wide for the gripper to pass. This slot is placed a little to one side of the tube to prevent sand and grit from falling on the rope as well as to enable the gripper to pass by and under the upper sheaves and over the lower sheaves in the tube.

The connection between the cars and rope is made by means of the gripper which will be explained later on. The cars are made to seat 14 persons and the grip-car 16 persons; but during the crowded portions of the day the car often contains as many as 44 persons and the grip-car as many as 26 persons — a total of 70. The grip-car is fastened firmly to the passenger-car so that there can be no danger of accident.

The passenger car is amply supplied with brakes, there being besides the ordinary brake, an attachment operated from the platform in the same manner as ordinary brakes which forces a broad block of wood down on each rail immediately under the car — this arrangement is shown in Fig. 6, Plate 7. (a) — ; and also strong iron drags are provided so that in case of accident they will prevent the car from going down hill by catching in the street. When necessary to back down hill these drags are raised up out of the way. The grip-car is also provided with powerful brakes.

The grip and passenger cars are so connected as to utilize as much as possible the weight of the car going down hill in drawing up the cars on the other track. In going down hill the car goes at the same rate as the cable and consequently the brakes are only needed when stopping.

The System as represented in the plates is as follows:

Plate I gives a view of the Clay Street Hill Railroad in operation.

Plate V — Fig. 1 — gives a profile of the street, showing the grade.

Plate VII — Fig. 6 — gives a side elevation of grip and passenger cars and also a longitudinal section of road and tube.

(a) is the brake that acts on the track directly under car.

(b) is the manner of coupling grip and passenger cars.

(c) is the gripper.

(d-d-d) are upper sheaves for keeping rope down where the grade changes upward.

(e) is one of the supporting pulleys.

Plate VIII — Fig. 7 — is a transverse section through the grip-car and road-bed. The tube, supporting pulley, rope, and gripper are shown as well as the general construction of them and the road-bed.

Plate IX — Fig. 8 — is an isometrical view of the road-bed with a portion of the tube removed to show the attachment of the gripper to the rope. The construction of the frames for the tube as well as the construction of the tube itself are clearly shown. The appearance of the rails and slot are also seen.

Plate X — Fig. 9 and 10 — show the gripper. A vertical slide, (a) Fig. 9, works in a standard (b) and is connected to a screw (c) [shown in Fig. 7.] which passes through the centre of the screw (d) and is worked by the hand wheel (e). At the lower end of the slide (a) is a small wedge-shaped block (not shown in figures) which is connected to the slide. The rope is grasped by two jaws — one of them (f) being made to the standard (b) and the other (g) having a horizontal motion. By moving the slide (a) upwards the wedge closes these jaws upon the rope and by mov- the slide downwards the jaws are loosened. The jaws are faced with soft cast-iron which is easily removed when worn out. On both sides of these jaws and attached to them are small sheaves (h) which are held by rubber cushions sufficiently in advance of the jaws to keep the rope off of the jaws and at the same time to lead the rope directly between them. Thus the rope is held directly in place by means of these sheaves and does not touch the jaws when they are open, but passes freely between them. When it is required to grip the rope the jaws are closed by means of the wedge and at the same time the sheaves are forced back on the rubber cushions.

The standard (b) is enclosed and retained in an iron bracket, as shown in figures. It is raised and lowered bodily through an opening in the tube, from above the surface of the street to the moving rope in the tube, by means of the screw (d) and the hand-wheel (i). The iron bracket holding-gripper is secured to the grip-car.

Fig. 11, shows a section of the road-bed. The slot of the tube is on one side of the centre for reasons before stated.

The foot of the gripper is ⊥ shaped in order to allow it to pass over and under the rope sheaves in the tube. To stop the car the jaws of the gripper are loosened slightly and the brake put on — the guide sheaves on the gripper retaining the rope in place.

The shank of standard (b) is ½ inch in thickness and 7½ inches in width, thus allowing ⅛ of an inch play on each side between standard and side of slot. All of the essential parts of the gripper are made of steel.

Plates XII and XIII show plan and elevation of engine-house and the manner in which cable is run.

The rope runs 17½ hours per day at a speed of six miles an hour. The cars start every five minutes except in the afternoon when they run every three minutes.

The road has a guage of 3'-6". An ordinary 30 lbs steel T rail is used, which is set flush with the street. The machinery is so arranged that the rope passes for some distance in open view of the engineer so that it can be readily examined at any minute.

— Sutter Street Railway. —

After the Clay Street Hill Railway had been in running operation for three years and a half, and the economy and practicability of the system had been thoroughly tested, the Sutter Street Railway, which had been run for years unprofitably by horses changed their road to a cable road. This company now has 1700 feet of double track operated by cable. The guage of the track is five feet and its greatest elevation above its initial point is 167 feet.

The grades are comparatively light and consequently this road presented an opportunity to compare the cable system with that of horses, on ordinary roads.

The comparison was not under the most favorable circumstances as the business of the road was not interrupted during the change and consequently the construction could not be of the best. Not-with-standing this, in a statement made by the superintendent and secretary of the road, the running expenses showed a saving of 30 % and the passenger traffic an increase of 962.375 passengers during the first year.

The passenger as well as the grip-cars of this company seat eighteen persons each.

The main cable is 13.291. feet in length. A branch cable road runs at right angles to this on Larkin St. and is 3.712 feet long. The latter road runs across two other cable roads — viz the California and the Geary St. roads.

Plate II shows a viey of the Sutter Street Railroad.

Plate VI — Fig. 5 — gives a profile of this street showing elevations.

Plate XI — Fig. 12 — shows gripper used on this road. It is different from that used on Clay St. although the principles involved are the same. The motion of the gripper jaws is vertical instead of horizontal and it takes and releases the rope sideways instead of beneath; and in order to run on or off from the rope at the termini of the road, the track and slot diverge from, or converge to the line of the rope. Levers are used instead of screws for operating the jaws.

California Street Railway

This road commenced operation April 1878. Its length is 12000 feet of double track and it passes in that distance over two elevations, their heights being 265 and 235 feet above their respective bases. The guage is 3½ feet.

This road like the Clay and Sutter St. roads has been extended beyond the length of its original construction which was 8800 feet and which was constructed in a very substantial manner.

The engine-house is located in a valley about midway between the ends of the original road. Some of the grades in this line are quite heavy there being a rise of 67 feet and of 75 ft. in distances of 412½ feet. This is the heaviest grade in San Francisco, with the exception of one block on the Presidio road, which has a rise of 78 feet in 412½ feet.

This company uses a heavier rope than the other lines of the city, the rope being four inches in circumference. The driving pulleys are on the same plane as the rope and situated under the street.

The gripper employed is worked by a lever and takes the rope from the side.

Plate IV gives a view of the street.

Plate V—Fig. 2—shows profile of the street.

—Geary Street Railway—

This road runs over a comparatively level street and through the most central and popular streets of the city. It commenced operation March 1880.

The guage of the road is five feet and its length is 13,200 feet of double track in which distance it passes over two elevations 360 and 250 feet; respectively above base and reaches an elevation at its west end of 224 feet above base. Its starting point is 35 feet above base and the two intermediate valleys respectively 160 and 154 feet above.

The tube is constructed in cast-iron sections and then covered with concrete. The space inside of the tube is much smaller than that of any of the other roads. The gripper is worked by a lever. It is vertical in its motion and takes the rope from above, the gripper-jaws being immediately under the slot as is also the rope. The rope consequently is always exposed to falling water and dirt from above. This has been avoided in the other roads by placing the rope and consequently the gripping-jaws far enough to one side of the slot.

Plate IV shows a view of this road.
Plate V—Fig. 3— gives a profile of the street.

Presidio and Ferries Cable Railroad

This road has 10,000 feet of double track. It ascends one hill 246 feet above its initial point in a distance of 5000 feet. The engine is located on the summit of the hill about midway between the termini; and about 700 from the engine house is the grade, 78 feet in 412½ or 1 in 5-3/10. The road is built very substantially with cast-iron sections or yokes, connected by rolled channel-iron and sheet-iron.

The gripper is the same as the one used on Clay St. although made heavier in consequence of heavier grades and rolling stock.

There is a curve at the intersection of two streets about 2600 feet from the starting point, and the rope is deflected by means of two sheaves eight feet in diameter, which lie horizontally. The streets descend from both directions towards the curve and, when the car is within about thirty feet of the curve the rope is dropped by the gripper, and the car is carried around the curve by means of gravitation, the rope being again picked up after passing the curve.

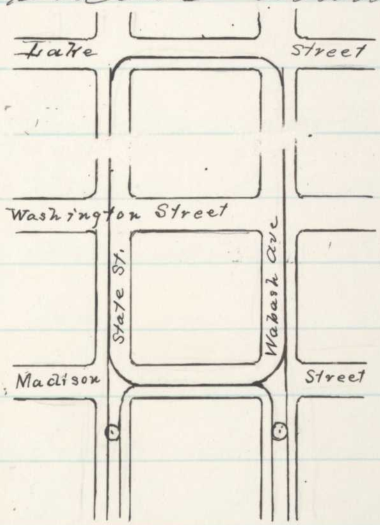
Part IV.

Description of the Chicago Cable Railway.

The Chicago Cable Railway was first put into operation January 1882. It is the longest and most complete cable-road yet constructed. It has between nine and ten miles of double track now in operation, there being four miles on State St., two miles on Wabash Ave, three miles on Cottage Grove Ave., and some auxiliary tracks which are short. The length of the entire cable is 21 miles, and the longest single cable is six miles. These cable-roads are connected with the business portion of the city and consequently can not run with the speed in that portion of the city which they can in the resident portion. When first constructed it was intended to give the cables south of 22nd St. a speed of ten miles per hour: and north of 22nd St. a speed of eight miles per hour: but this speed has never been attained, the cables now running at about 3/5 of this speed.

The streets all being level in Chicago the difficulties attending the running of cables over grades were avoided.

The engine-house is on the corner of State and 21st Streets: and from here all of the main cables are operated — one cable runs north on State St. to Madison a distance of two miles; a second runs south on State St. two miles; a third is carried from the engine-house to the corner of Wabash Ave and 22nd Sts., (one block in distance) where it commences operation with the cars—it runs north from this point on Wabash Ave to Madison a distance of two miles; a fourth cable is carried a distance of 1,920 feet from the operating room to the intersection of Cottage Grove Ave. and 22nd St., where it commences operation and runs a distance of about three miles south. Besides these four cables, there is some auxiliary cable—for instance; at the terminus of the cable at State and Madison, an auxiliary cable is connected by means of a second sheave which is on the same spindle with the sheave driven by the main cable. This auxiliary cable runs from its connection with main sheave down Madison St. one block to Wabash Ave, then



north to Lake, then west back to State St. and down State to the starting point. At the terminus on Wabash Ave is a similar auxiliary cable. The track around this "belt" as it is called is single and consequently has two cables, one connected with the State St. cable and the other with the Wabash Ave cable. This belt line avoids the use of shunting devices to change cars from one track to the other

The rope used is four inches in circumference and made of Swedish iron and is composed of six strands of 19 wires each. All the driving and angle sheaves around which the cables pass, are twelve feet in diameter, except in case of belt-lines whose sheaves are six feet in diameter.

Each cable receives its motion from two driving sheaves, both of which are directly connected with the engine. After passing around the driving pullies several times the cable passes back over a twelve foot sheave mounted on a carriage and from thence out under the street. This carriage is connected by means of a chain with weight hanging in a well to give the rope a constant tension.

The engines are four in number, only two of them being in use. They are of the "Wheelock" pattern: the cylinders being 24 inches in diameter by 40 inch stroke with a capacity 250 H.P. each. The boilers are in four sets of two each, of what is known as the Babcock and Wilcox pattern.

The tube or tunnel, is made much deeper than those of San Francisco: for in consequence of the level streets, greater depth of tunnel is needed to secure proper drainage. There are many designs for road-bed and tunnel construction and no two of them have as yet been constructed alike. The climate, nature of soil, and grade of streets have to be taken into consideration - besides different persons advocate different materials for construction.

To secure proper drainage the tunnel is made rather deep, being from 3'-4" at the summit to 3'-7" at catch-basins: and the catch basins are situated every 300 feet. This gives with the grade of the streets a fall of 3½ inches in 100 feet. The catch-basins are connected with the city-sewers by means of over-flow pipes. There is no objection to deep tunnels and this will probably be found none too deep to properly drain off the water after some of the severe winters which they have in Chicago. The rope is held up by small sheaves every 39 feet and runs at a distance of 21 inches from the surface; thus giving plenty of room beneath for drainage.

The road-bed and tunnel are constructed the same around curves as along straight lines except that conical pullies are used on curves to hold the cable as near the proper curve as possible. The conical pullies are placed eight feet apart, the curves having a radius of from 40 to 60 feet. An angle-iron is also bolted to the slot-rail inside of tunnel at curves to take the lateral strain off of the gripper as much as possible.

Places where a new cable is to be taken up by the gripper; the cable is raised to the height of the gripper by small sheaves and thus passes right into the jaws of the gripper. The gripper taking the cable from the side

The greatest expense incurred in the construction of a cable-system is the road-bed and tunnel: which in Chicago amounted to nearly $100000. per mile of double track. Even though the Cable Railway Co. of San Francisco gives in their tables $51,899.56 as the estimated cost of construction per mile of double track; yet few of those already constructed have cost less than $100000. per mile of double track.

The gripper of this road is different and far superior than that of any San Francisco road. It is double so as to be able to catch a cable on either side. It works by means of a lever and catches the cable from the side. The jaws are faced with brass blocks which may be replaced when worn out. Wood was used at first but brass was found to be equally ~~as~~ good and to last longer. When so desired the cable is dropped by means of conical pulleis which throw it out of the jaws — the jaws being open; but when once dropped it cannot be regrasped by the gripper except where it is carried up to the gripper by means of small sheaves — the jaws of the gripper being thirteen inches below the surface of the street and consequently eight inches above the rope when it is on the supporting pulleis. When the gripper changes cables it drops the one and the car moves along by means of its momentum until the other cable is carried into the jaws on the other side of the gripper.

The brake used is very powerful, stopping the cars almost instantly and yet without a jerk. It is worked by a lever within reach of thy operator of gripper.

This system is in operation twenty hours daily and carries on an average of 70,000 pas-

sengers during that time. It may seem incred-
ible yet State itself has a carrying capacity of 10,000 passengers per hour; and the whole system of about 20,000 passengers. The saving by the employment of this system is said to be from 30 to 50 per cent on that of horse power.

Plate XIV - Fig. 15 - gives a view of grip-car and gripper and a view of cable.

(a) is the lever by which the gripper is worked, the operator standing in an enclosed portion around lever.

(b) is the lever by which the brake is worked.

(G) is the gripper with rope grasped.

(l) is position of rope when on carrying pullies.

(P) is one of the carrying pullies.

Fig. 16 - shows the curves in cable at the corner of Madison and State Sts: and the cervical pullies which hold cable in place.

Fig. 17 — shows section of road-bed and tunnel at curve, which is the same as section of straight line and a little more. The general frame-work, the manner of bracing slot, the position of rails, and the cement work are all clearly shown.

(a) is the angle iron on inside of curves and bolted to slot-rail to relieve strain on gripper.

(G) shows the gripper.

(P) is one of the supporting or carrying pullies.

Plate XV — Figs. 18 and 19 — show the machinery in vault at Madison and State Sts., where auxiliary connects with main cable.

(B) shows main cable which passed around the twelve foot sheave (C). On the return track it is raised to within 13 inches of the surface by means of the sheave (D) to allow the gripper to catch it. To allow the gripper to pass this sheave there is a small curve in the track, which carries the gripper around as shown in the drawing.

On the same spindle with the sheave (B) is placed a six foot sheave (E) which drives the auxiliary cable, the sheave being driven by the main cable.

The auxiliary cable comes in at (F), passes beyond the point where the main cable is grasped, and down over the sheave (G), then up to the driving pulley (H). After gaining sufficient amount of friction with the driving pulley, the auxiliary cable passes back over the tention sheave (T), and then up to the proper distance from the track and out at (H). It is raised high enough to be grasped by gripper by means of the sheave (I).

The tention pulley (T), is connected by means of a chain with the weight (W).

Plate XVI – shows view of brake, which is used on grip-car. The brakes of the other cars are attach-to, and operated by means of this brake.

(a) is a flange and hub made fast to the axle of the wheels.

(b) is another hub and flange which is loose on the axle. At the other end of the hub ~~has~~ a thread is cut which works in the nut (c).

The nut (c), is kept from slipping back and forth on the axle by means of the collar (d).

To the hub of the flange (b) is fastened the arm (e), which is connected to the lower end of the lever (f), by means of the link (g).

To the nut (c), is fastened the arm (h), which is also connected to the lower end of the lever (f).

The lever works on a fulcrum (k), and by pushing it in one direction the flanges are brought together and brake the car. By pushing in the opposite direction the flanges are opened. By having the lever connected with both nut and flange it is kept under better control and worked with more rapidity.

The arm (e), is made so that the extra play may be taken up. Between the flanges is a heavy piece of leather.

Plate XVII is a view of the gripper.

(a) is the frame of the gripper and is set in bearings on the under side of the car, as shown in Fig. 15. To this frame ~~is~~ fastened the lower jaw of the gripper (b), by means of the strips (c).

(d) is the upper jaw of the gripper and is guided in its motion up and down, by the portions of the lower gripper (e.e). The upper jaw is connected to a broad, flat and thin piece (f), which runs up through the frame and ends in the arc (g).

The parts (f, c, c), are made thin as they have to slide along in the slot — the level of the street being on the line (h, h).

The lever has a moving fulcrum (j), which is connected to the point (k), of the frame by means of the link.

The lower end of the lever (l), is connected to the part (f) at the point (m). The fulcrum is adjusted one way by means of the set screw (n).

(o, o) are cone-pullies for throwing the rope out of gripper, they being raised against the rope by means of parts (p, p), which are connected to the upper jaw.

The jaws as shown in plate are closed. By loosening lever and pulling it in the direction of arrow, the moving fulcrum (f) slides up-on the lever and all pressure is removed from the upper jaw; except that of its own weight. The jaw is not raised however until the lever is pulled over far enough to make the angle, which the force along the link makes with the lever, greater than the angle of repose. Then the moving fulcrum remains stationary and the lever raises the upper jaw of gripper. As the upper jaw raises, it raises the cone-pullies (o, o) by means of the pieces (p, p). These cone-pullies act against the cable and throw it out of the jaws. After the cone-pullies reach a certain height they drop automatically, and the gripper is ready to grasp the other cable which is carried into the jaws on the other side. To fasten the gripper on the rope, the lever is pulled up until the upper jaw rests on the cable then the moving fulcrum slides down on the lever until the set-screw (n) strikes the shoulder (r) when pressure is brought to bear on the cable.

(s, s) are small guide pullies.

<u>Plate XVIII</u> shows plan of engine-house.

(a, a) are the driving pullies connected with the engines by means of shaft (h).

(b, b) are the tention pullies.

(c, c) are the wells in which the weights are suspended.

(d) is State St. cable running north.

(e) is State St. cable running south.

(e and f) are Wabash Ave and Cottage Grove Ave. cables.

The cables at right of engines are for prospective roads.

Part V.

Plates and Tables.

The plates and table of Part V have been gathered from various sources; and have given information on the subject which it would have been difficult to obtain otherwise — especially in case of the San Francisco roads. Such alterations as I have deemed necessary have been made.

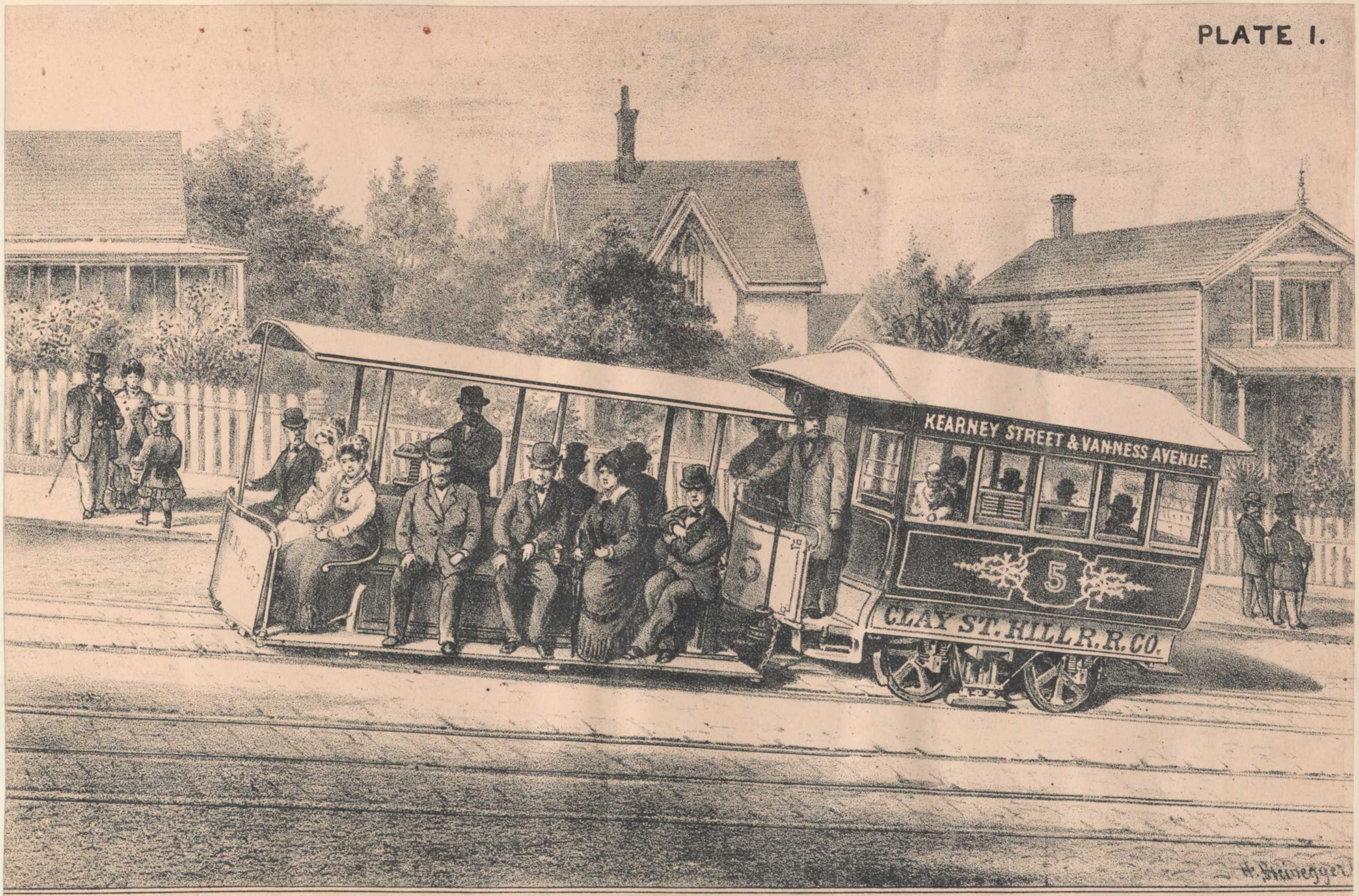
A great deal more could be said on this subject — as to the practicability and economy of running a double cable, the general management of a cable system, &c — but I leave it to other minds.

On the San Francisco roads, I am indebted for a great deal of my information to a pamphlet issued by the Cable Railway Co. of San Francisco.

The following Table shows the condition under which the Cable Roads named operate.

Names of Roads	Clay St. Hill R.R.	Sutter St. R.R. Co.	California St. R.R.	Geary St. R.R.	Presdio R.R.	State St. of Chicago City R.R	Entire Chicago System
Commenced Op.	Sept. 1. 1873	Jan. 27. 1877	April 9. 1878.	Feb. 16. 1880.	Dec. 9. 1881.	Jan. 28. 1882	Jan. to Dec. 1882
Length of road, double track.	5.300 feet	On Sutter St. 13.291 ft. On Larkin St. 3.712 ft	12.651 feet	13.200 ft.	10.500 feet	24.812 feet	21 miles
Heaviest Grade	307 ft. in 2.800 ft.	167 ft. in 4.300 ft.	265 ft. in 2.800 ft	83 ft. in 1925 ft	246 ft. in 5000 ft	Level	Level
Number Engines Employed.	Two	Six-4 on Larkin St. Two on Cemetary Ave	Two	Two	Two	Four	Four
Dimensions of Cyl.	14 x 28 in.	12 x 24 in.	22 x 36 in.	18 x 48 in	18 x 36 in.	24 x 48 in.	24 x 48 in.
Piston Speed per M.	632 feet.	340 feet.	570 ft.	368 ft.	348 ft.	365 ft.	365 ft.
Number of Boilers	Two	Six	Three fire-box	Three steel	Three	Four	Eight.
Diameter & thickness of Shell	16' x 54", 5-16ths thick 16' x 48". 5-16ths thick	2 – 64" x 16", 3/8" thick 3 – 48" x 16", 3/8" thick 1 – 52" x 16", 3/8 thick	57 in. diam, 7/16 thick	16" x 62", 3/8 thick	16' x 52", 5/16 thick	Bacock and Wilcox	Babcock and Wilcox
Number and size of tubes	42 - 3" tubes 56 - 3½" tubes	53 - 3 in. tubes 53 - 3" tubes 58 - 3" tubes 49 - 3" tubes	81 - 3" tubes, 12 feet long.	63 - 3 in. tubes Steel	73 - 3½" tubes	Sectional	Sectional
Average pressure	67½ lbs.	100 lbs.	70 lbs.	65 lbs.	75 lbs.	70 lbs.	70 lbs.
Presure necessary to move Cable	16 lbs.	40 lbs	15 lbs.	9 lbs.	42 lbs.	10 lbs.	——
Consumption of coal per day & kind	3,700 lbs. Wallsend, Sydney	24,640 lbs. Seattle nut coal	15,480 lbs. Seattle Screenings	11,230 lbs. Seattle nut	4,200 lbs. Cardiff	16000 Ind. Block	——
Wt. of empty car	2800 lbs.	3000 lbs.	4000 lbs.	4000 lbs.	4000 lbs.	5,825 lbs	5,825 lbs.
Wt. of empty grip-car	2100 lbs.	2000 lbs	3000 lbs.	4800 lbs.	4000 lbs.	5.150 lbs.	5.150 lbs
Intervals of Depart-	3 to 5 min.	4 min., average	5 min., average	2½ min. to 6 min	5 min.	3 min.	3 min.
Average no. of round trips daily	221	253	226	228	220	729	——
Average no. cars & Dummies employed	7 of each	14 of each	14 of each	16 to 20	12	87	——
Hours run per D-	17½	19½	19	19	19	20	20
No. wire ropes in use	One	4 - Sutter St. 3 Larkin St. 1	2	2	2	3	5 or 6
Lengthes of Ropes	11000 ft.	11587 ft. 7849 ft. 9800 ft. 8800 ft	8.840 ft. 17.055 ft.	16600 ft. 11000 ft.	10500 ft. 11000 ft.	20.594 ft. 22,966 ft. 4.321 ft.	3 each 4 miles long. 1. six miles long 3 miles aux. Cable
Circum. of Rope	3¼ inches	3 inch	4½ & 4 inch.	3 inch	3 inch	4 inch	4 inch
Kind of Rope	Crucible steel 16 strands, 19 wires	Crucible Steel 16 strands, 19 wires	Bessemer Steel 6 strands 19 wires	Crucible Steel 6 strands, 19 wires	Crucible Steel 6 strands, 19 wires	Swedish Iron 6 strands, 19 wires	Swedish Iron 6 strands, 19 wires
Speed at which Rope travels	528 ft per min	431 and 786 feet per minute	537 ft. per min.	600 and 650 feet per minute	600 ft. per min.	358, 716, & 804 ft. per min.	358, 716, & 804 ft. per min.
Average life of Rope	547 days	304 days	373 days	274 days	——	4 months	4 months

PLATE I.



CLAY STREET HILL WIRE ROPE RAIL ROAD.

ASCENDING AN ENCLINE OF ONE FOOT IN SIX. —— THE FIRST CABLE ROAD CONSTRUCTED.

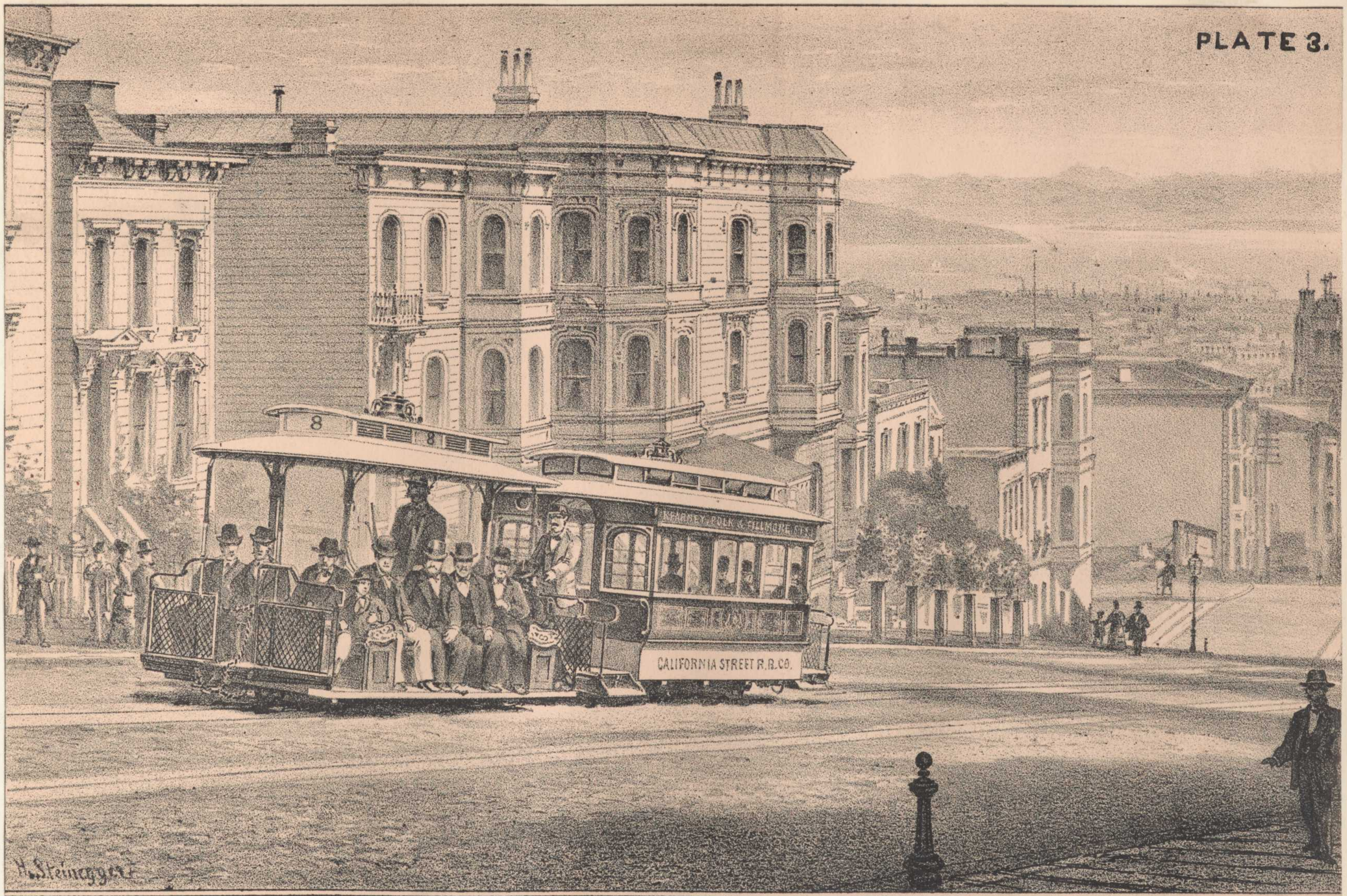
PLATE 2.

LITH. BRTTON & RE

SUTTER STREET WIRE ROPE RAIL ROAD.

THIS FORMERLY A HORSE ROAD, WAS CHANGED TO A WIRE ROPE ROAD.

PLATE 3.

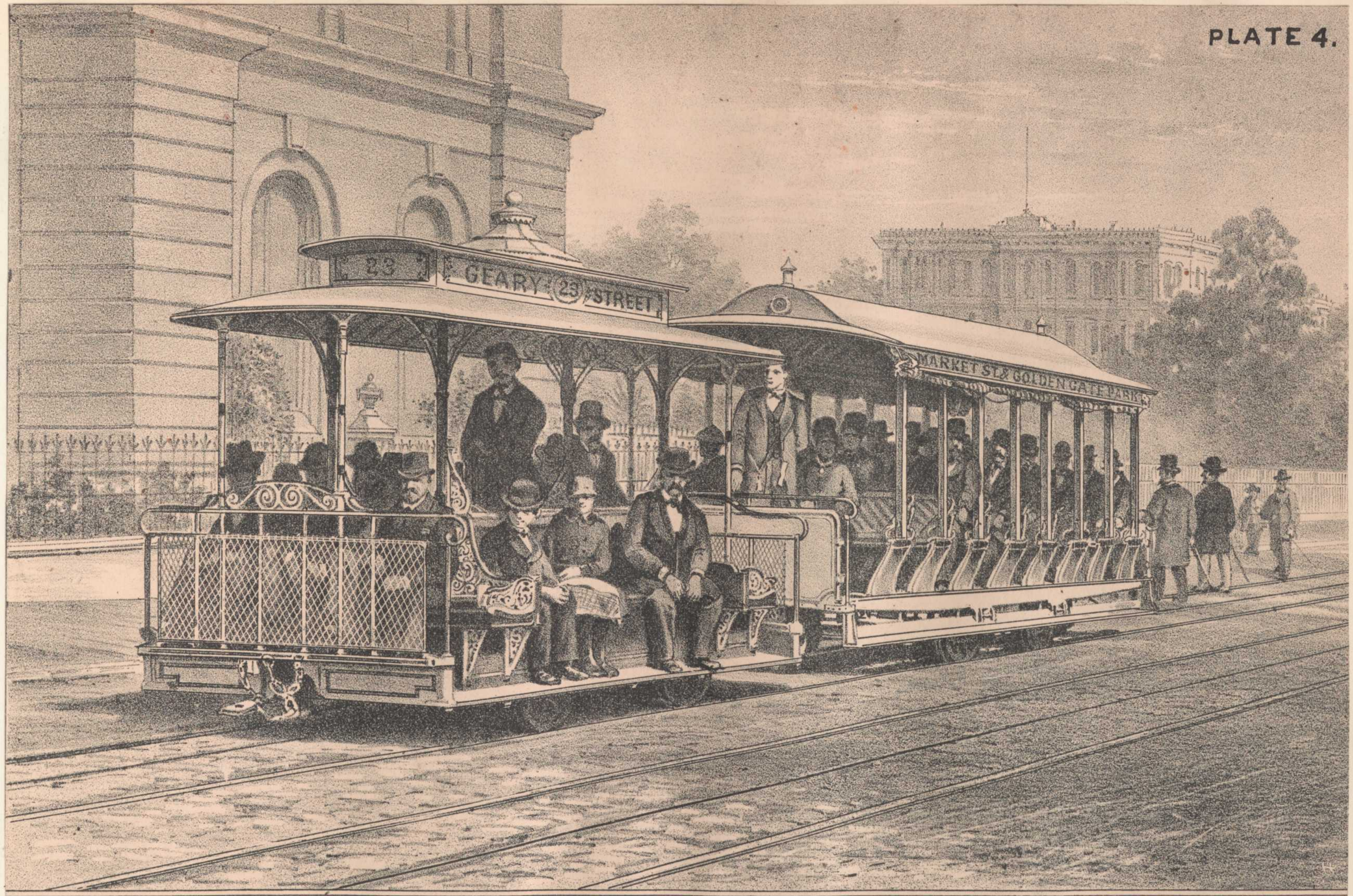


LITHO. BRITTON & REY

CALIFORNIA STREET WIRE ROPE RAIL ROAD.

AT A POINT 225 FT ABOVE THE BAY, HAVING ATTAINED AN ELEVATION OF 190 FT IN A DISTANCE OF 1375 FEET.

PLATE 4.



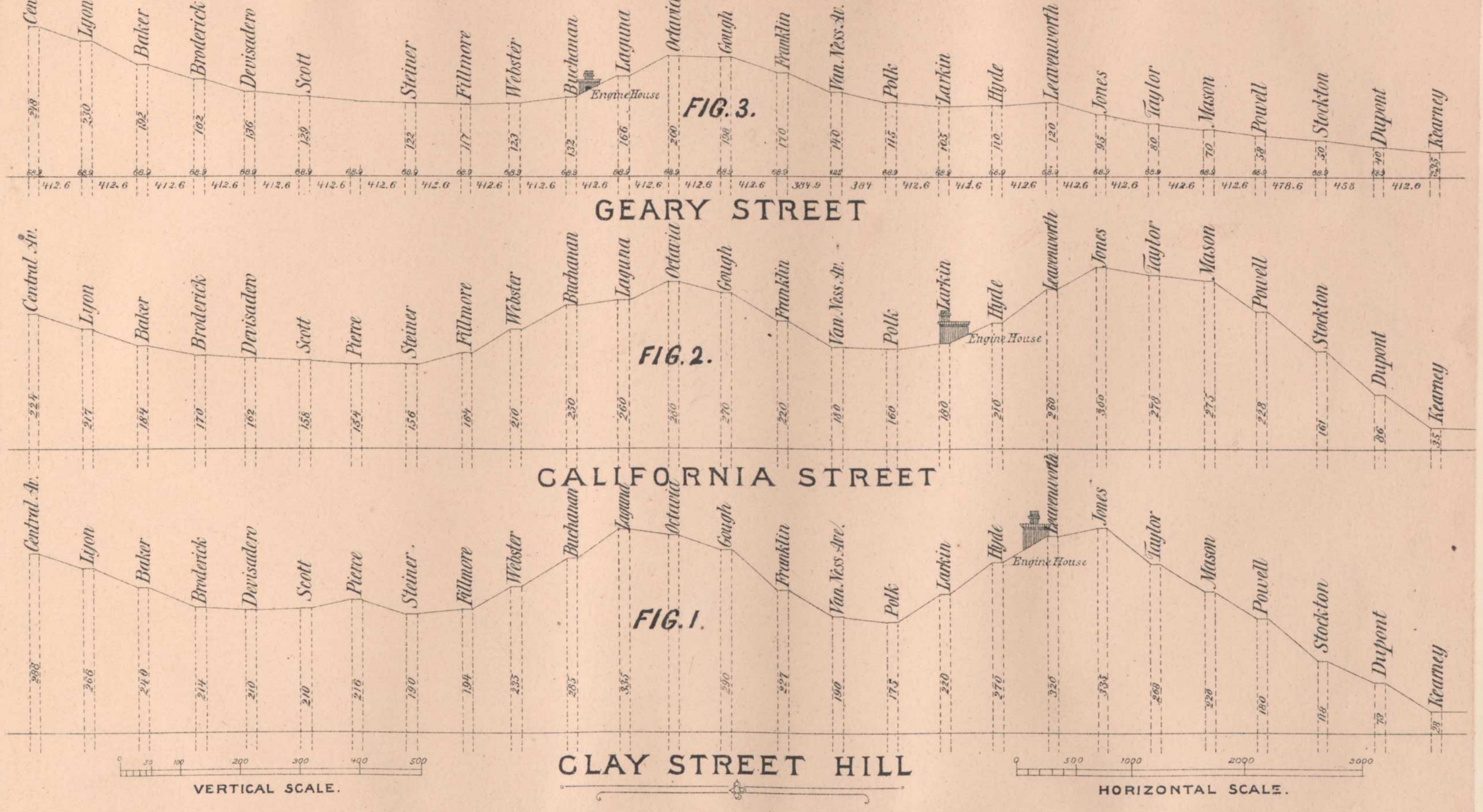
LITHO. BRITTON & REY, S.F.

GEARY STREET WIRE ROPE RAIL ROAD.

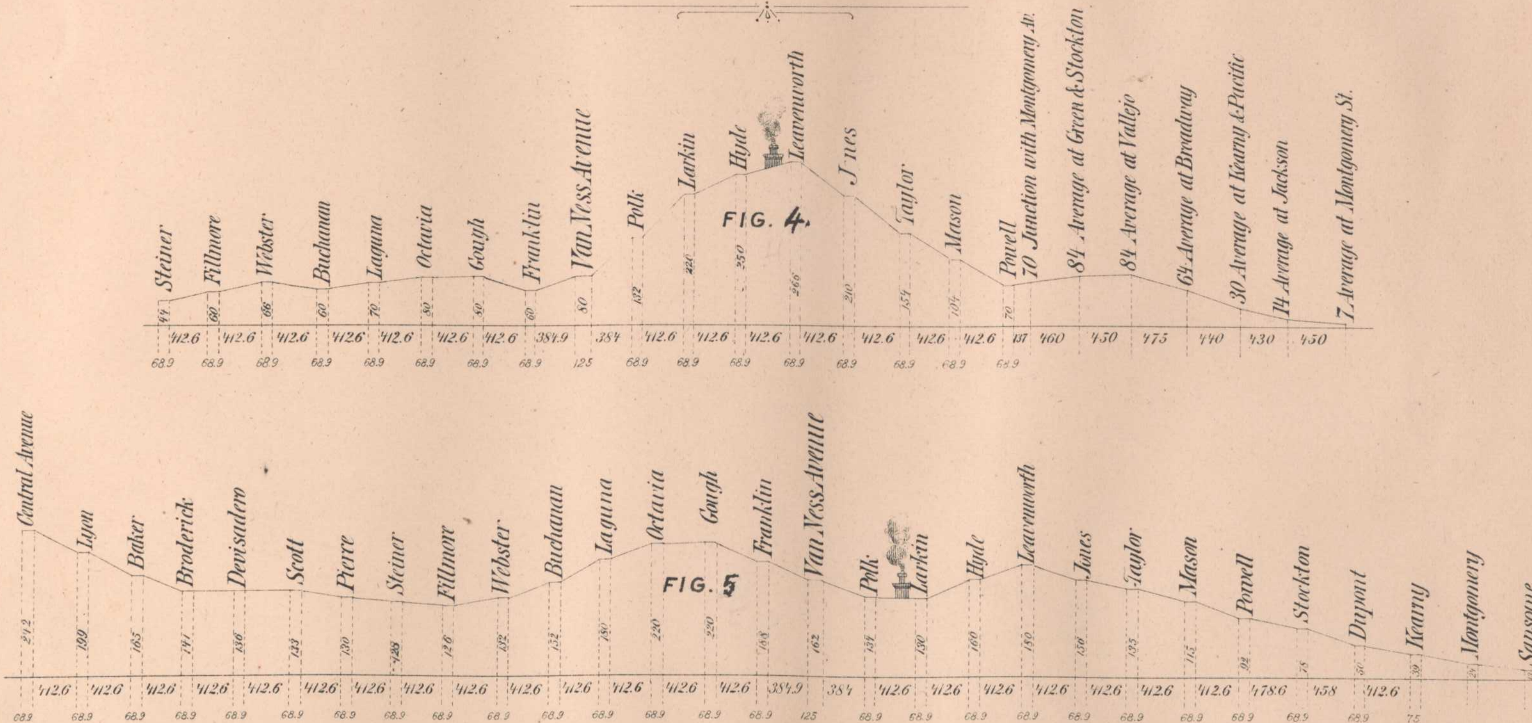
MUCH OF THE TRACK OF THIS COMPANY WAS FORMERLY AND IS NOW USED BY THE HORSE CARS OF OTHER COMPANIES.

PLATE 5.

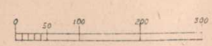
PROFILES OF STREET GRADES.



PRESIDIO RAIL ROAD.



SUTTER STREET.



VERTICAL SCALE.

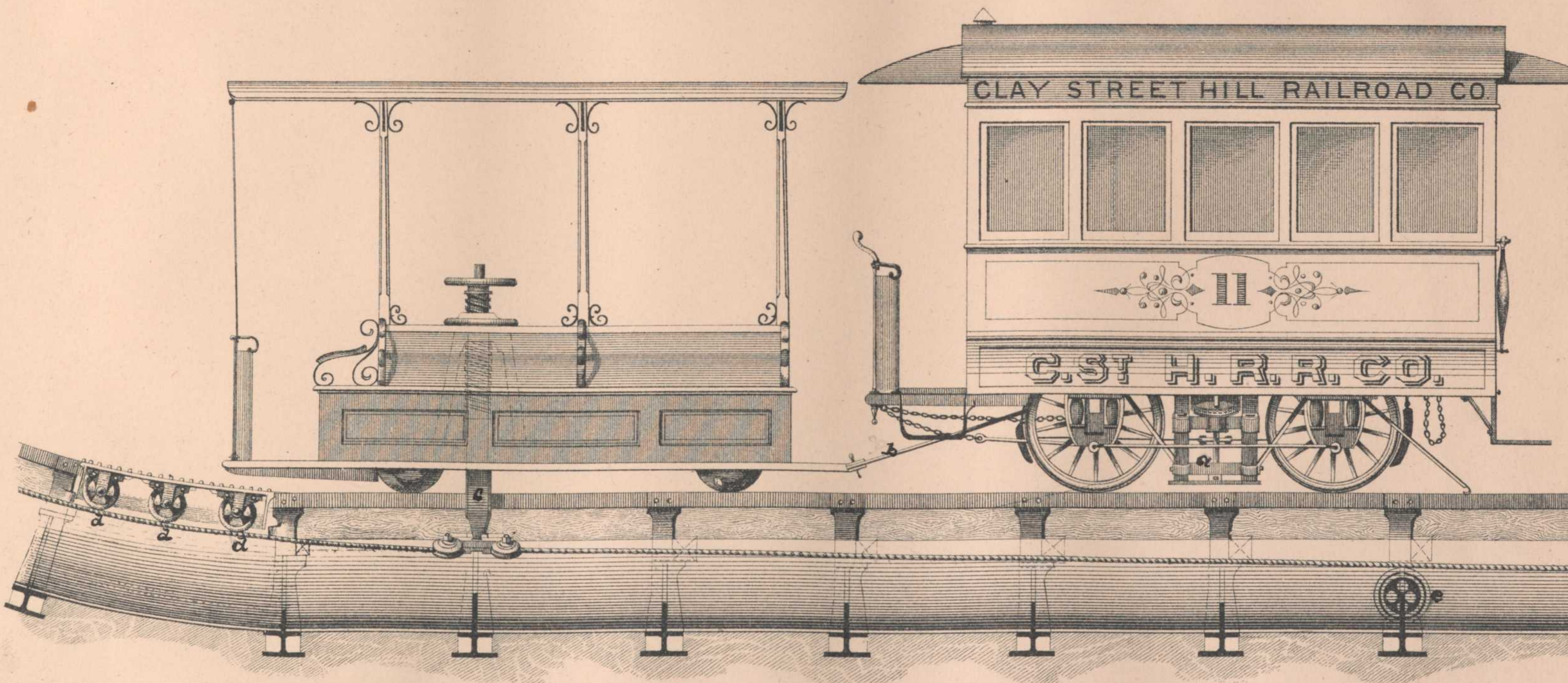
HORIZONTAL SCALE.

FIG. 6.

PLATE 7,

PASSENGER CAR AND DUMMY,

WITH GRIPPING ATTACHMENT, WIRE ROPE AND SIDE SECTION OF TUBE.



SECTION THROUGH DUMMY & ROAD BED

SHOWING CABLE AND GRIPPING ATTACHMENT.

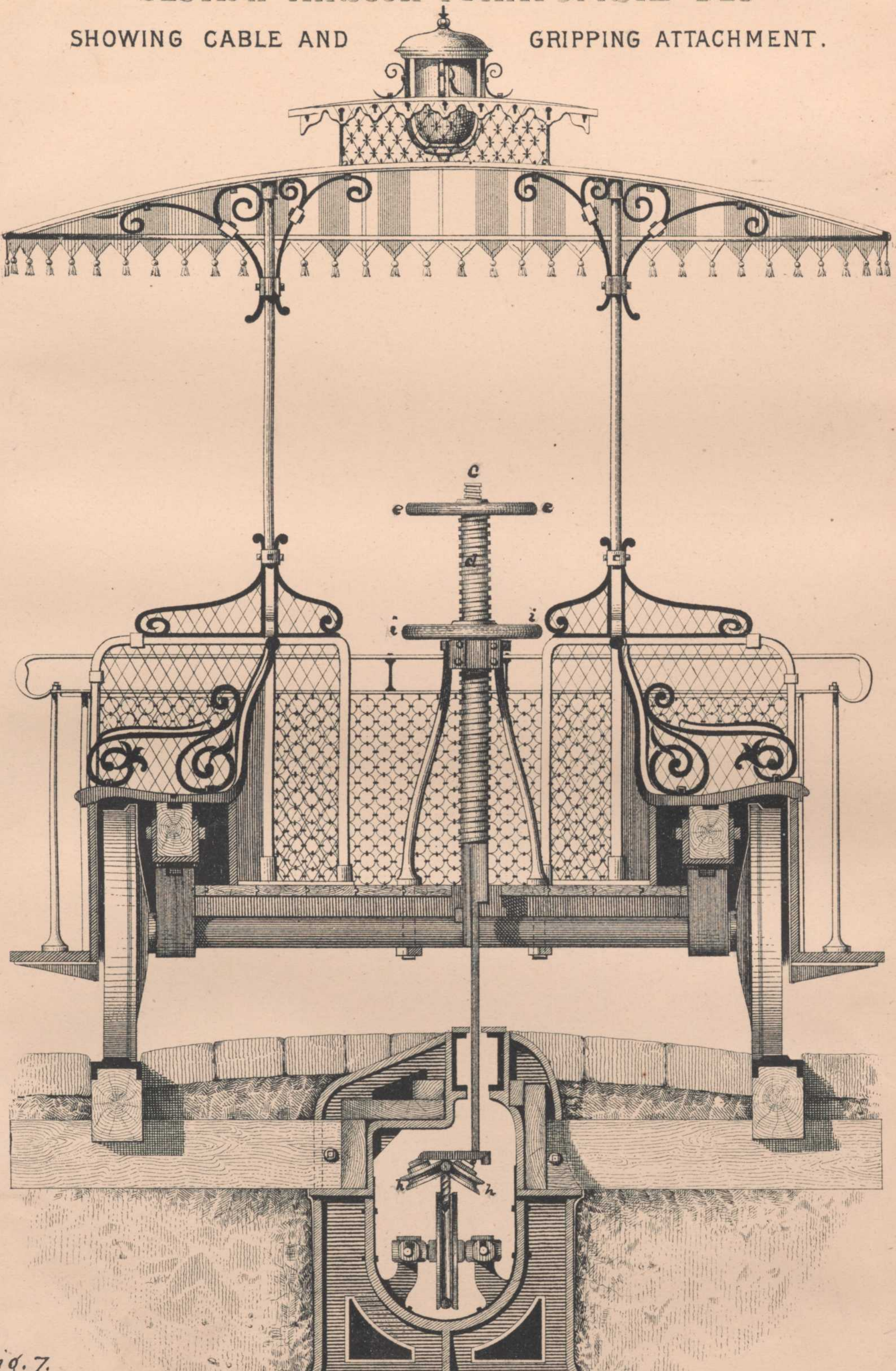


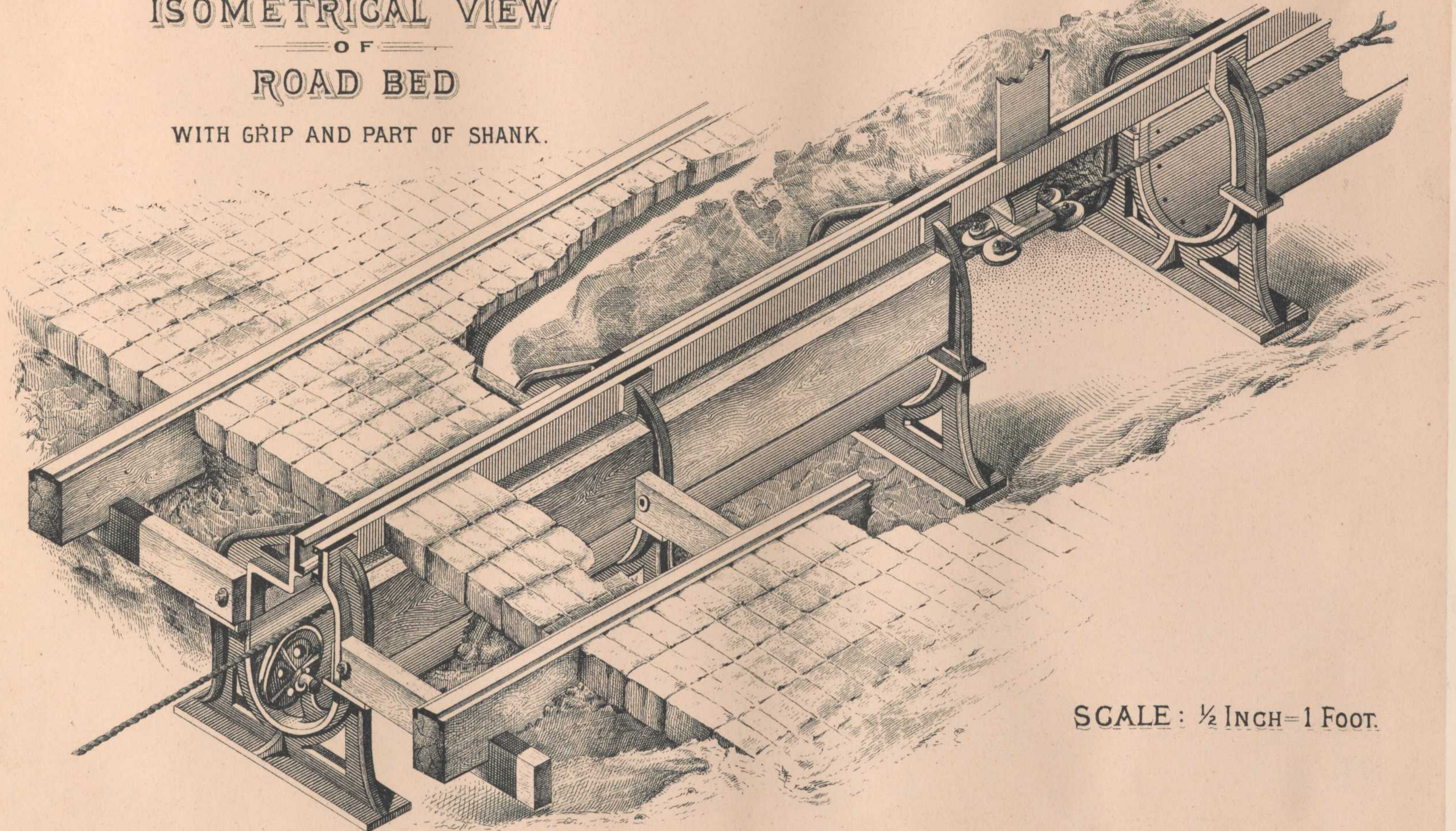
Fig. 7.

PLATE 8.

FIG. 8.

PLATE 9

ISOMETRICAL VIEW
OF
ROAD BED
WITH GRIP AND PART OF SHANK.



SCALE: ½ INCH = 1 FOOT.

FIG. 11.

CROSS SECTION OF TUBE, PULLEYS, ETC.

OF

CLAY ST. HILL R. R.

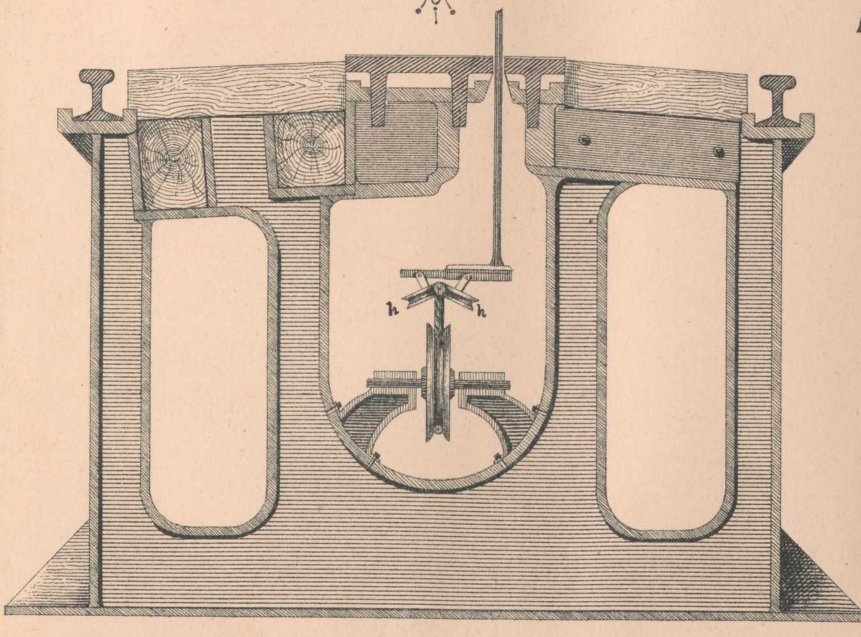


FIG. 9 SKELETON VIEW OF GRIP.

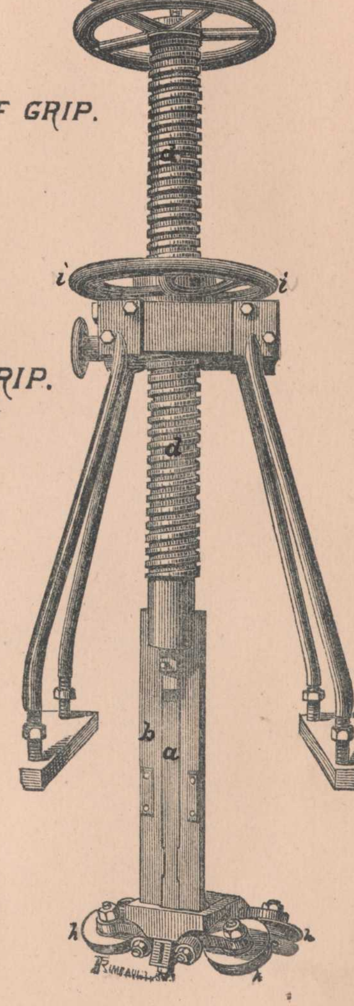
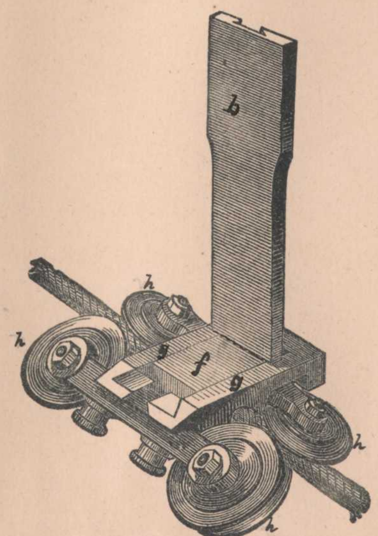


FIG. 10.

PERSPECTIVE VIEW OF GRIP.



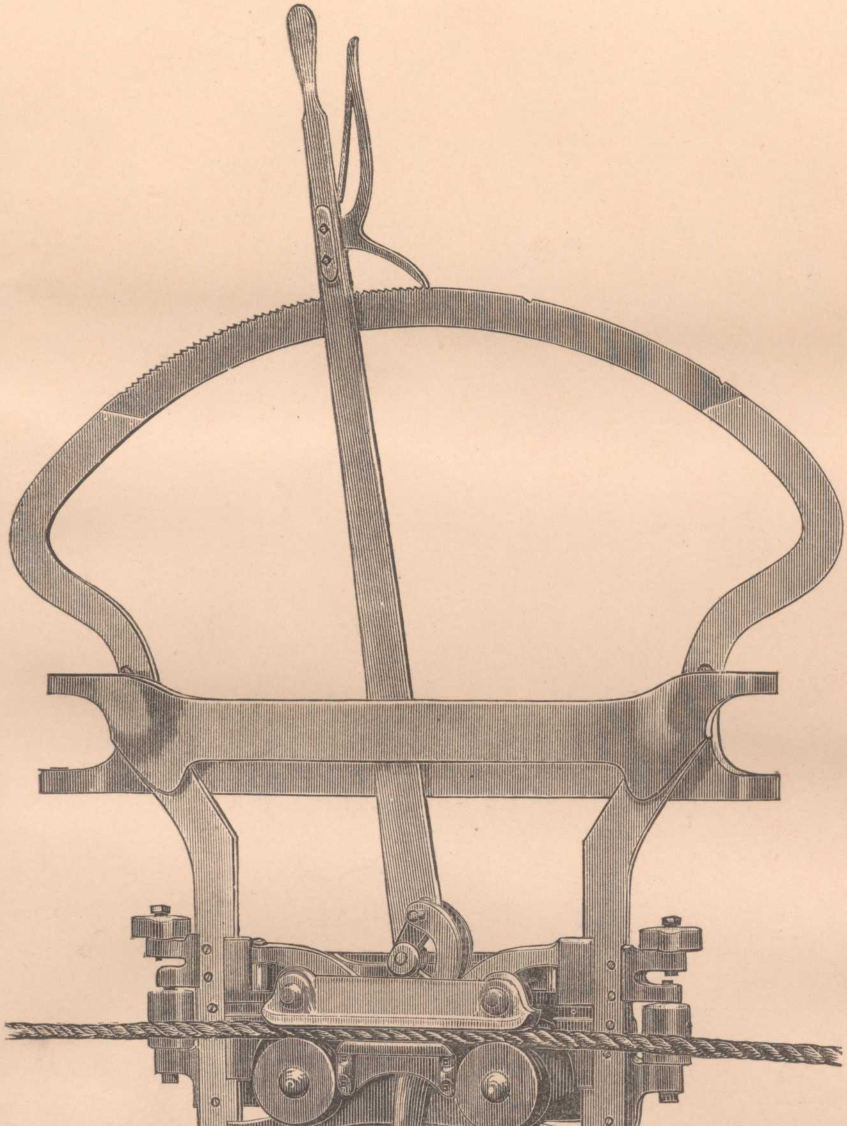
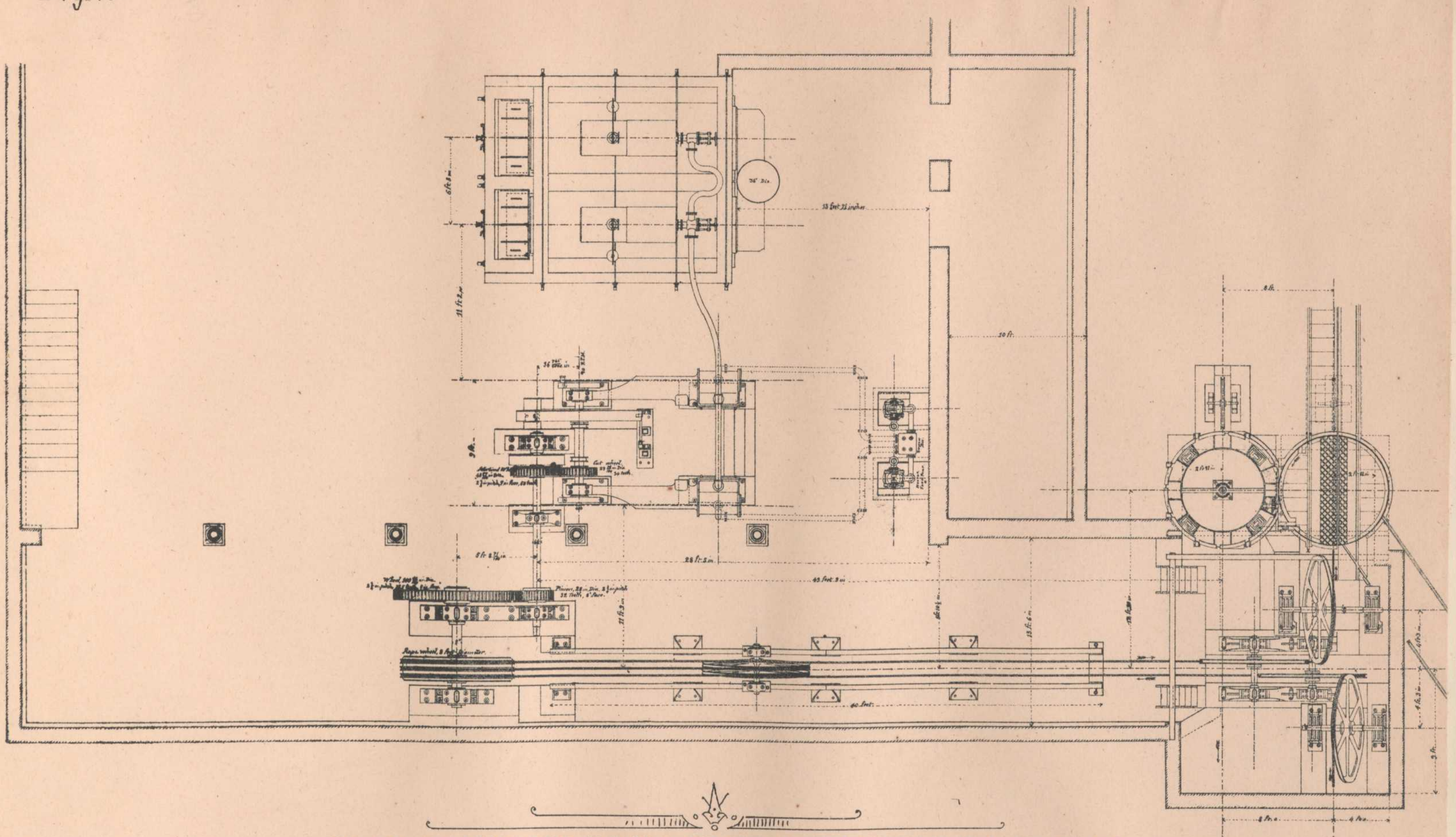


Fig. 12 Sutter Street R. R. Co's Grip.

PLATE 11.

Fig. 13.

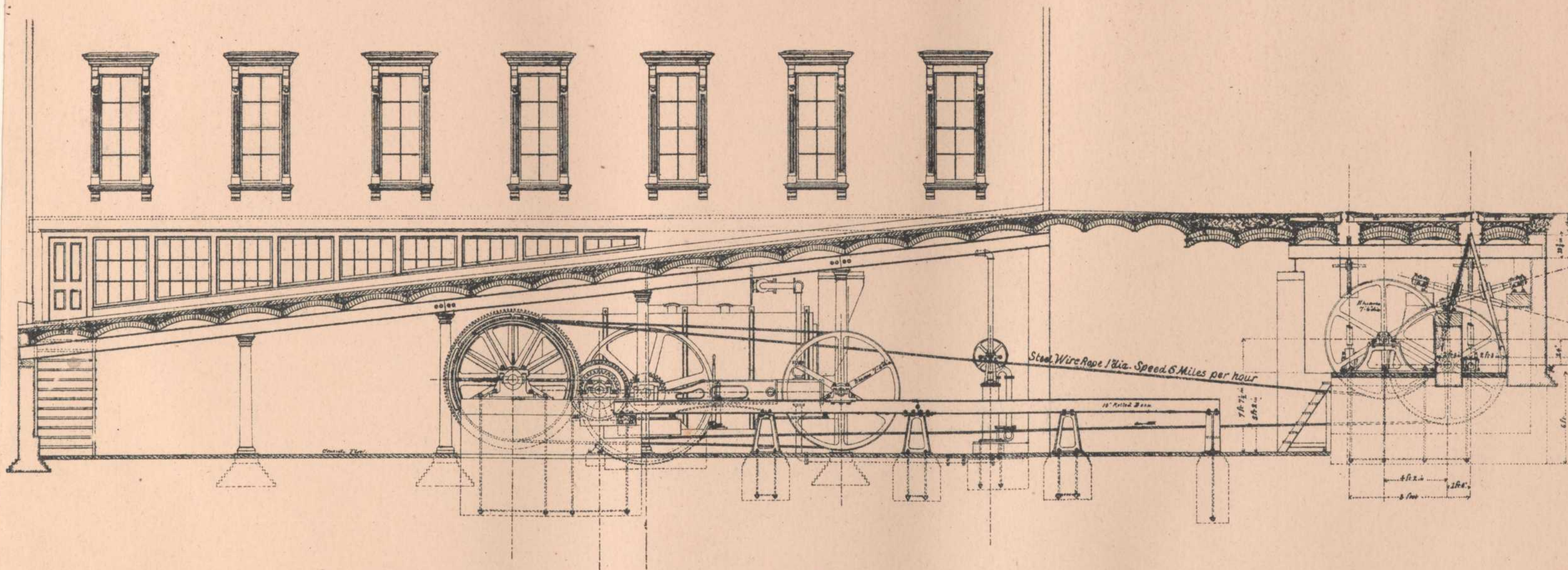
PLATE 12.



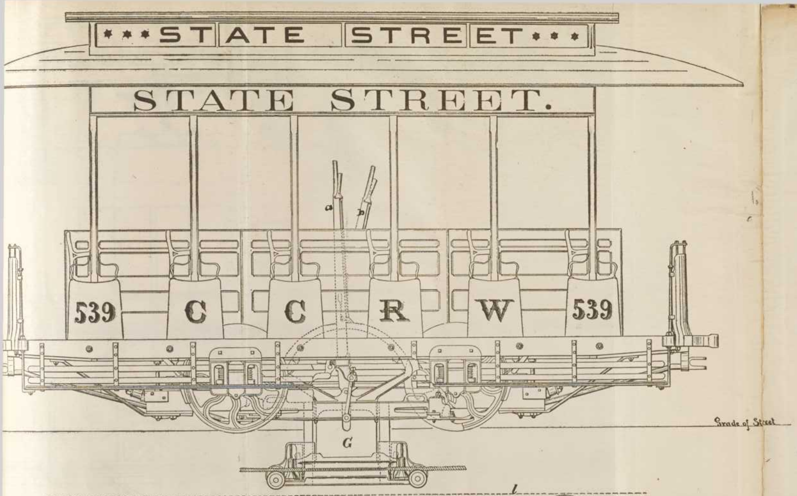
PLAN OF ENGINE ROOM OF CLAY STREET HILL R. R. Co

Fig. 14.

PLATE 13.



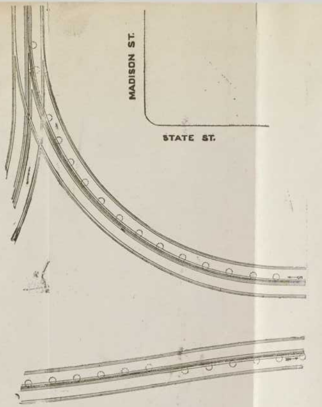
ELEVATION OF ENGINE HOUSE OF CLAY STREET HILL R.R. Co.



Side-Elevation of Grip & Grip-Car.

Scale, ½ in. = 1 ft

Fig. 15.



PLAN OF CURVES AND CROSSING.

Fig. 16.

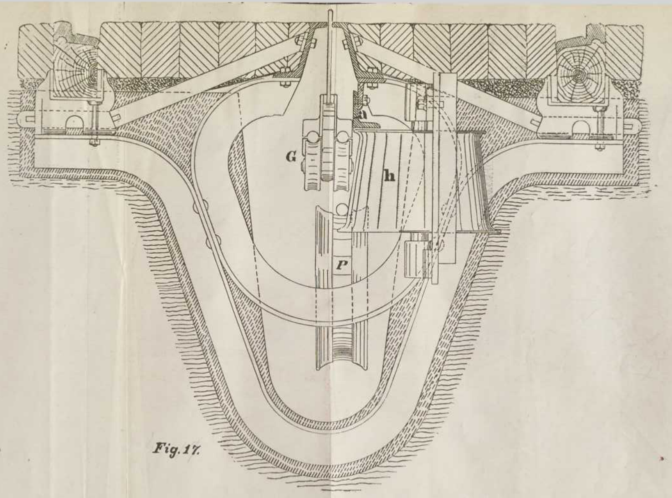


Fig. 17.

Section of Track at Curve.

Scale, 1½ in. = 1 ft.

—PLATE 14.—

CHICAGO CABLE ROADS.

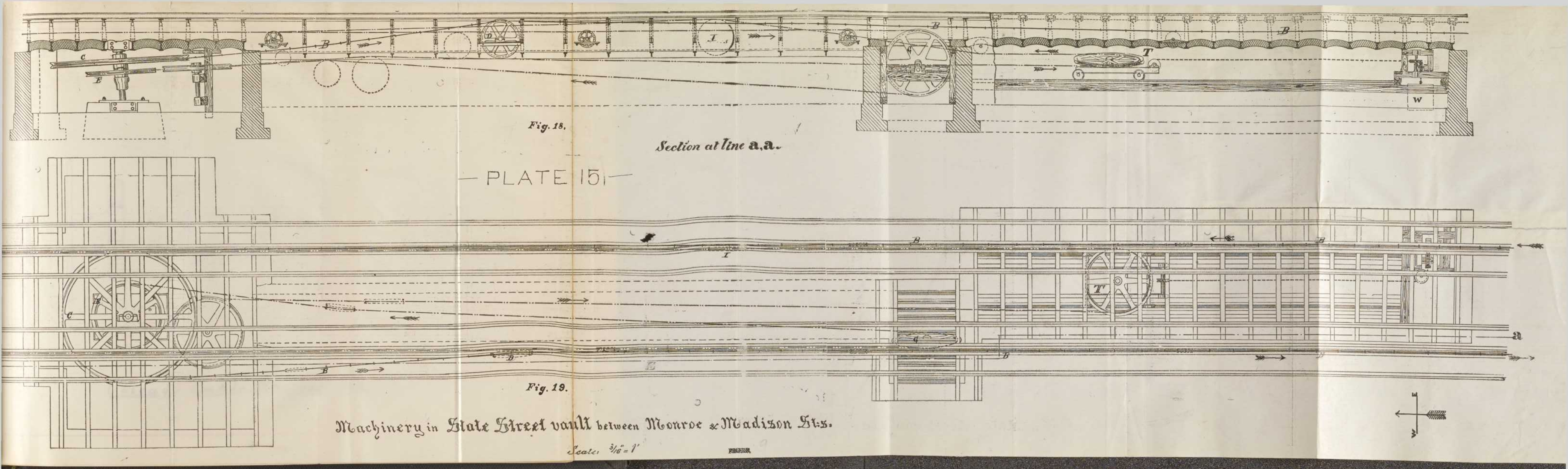


Fig. 18.

Section at line a.a.

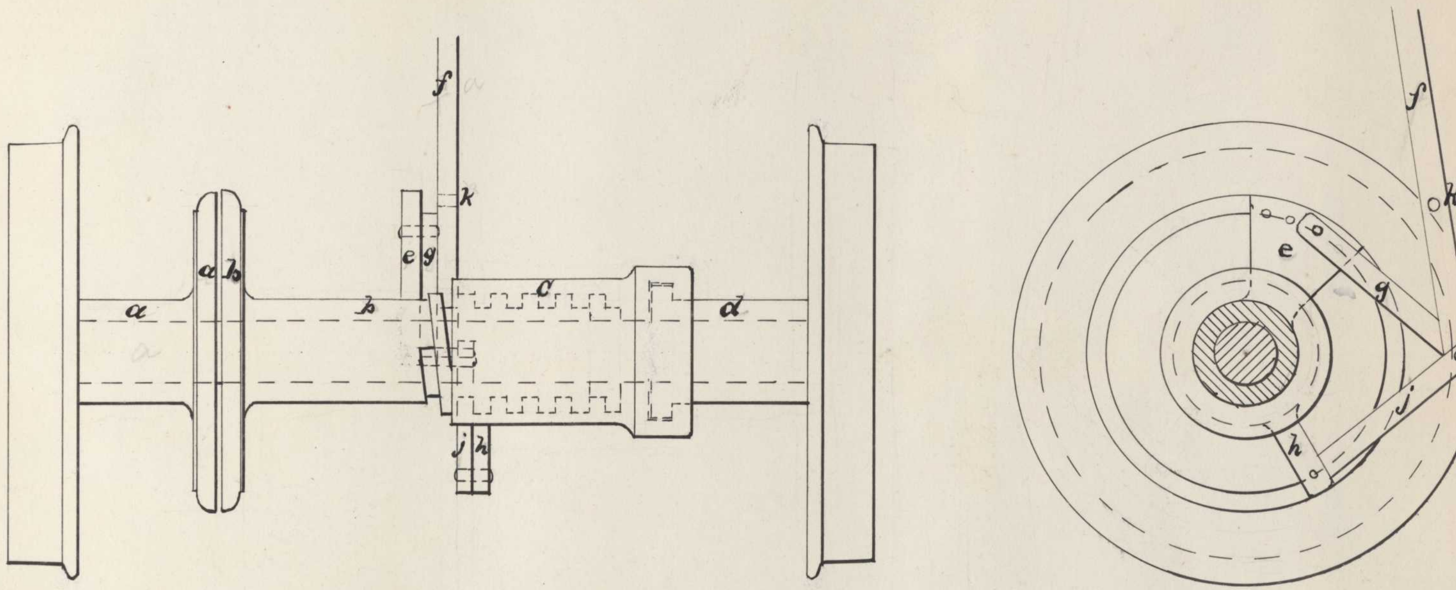
PLATE 15

Fig. 19.

Machinery in State Street vault between Monroe & Madison Sts.

Scale: 3/16" = 1'

Fig. 20.



—Brake.—

Chicago Cable Railway System.

Fig. 21.

PLATE 17.

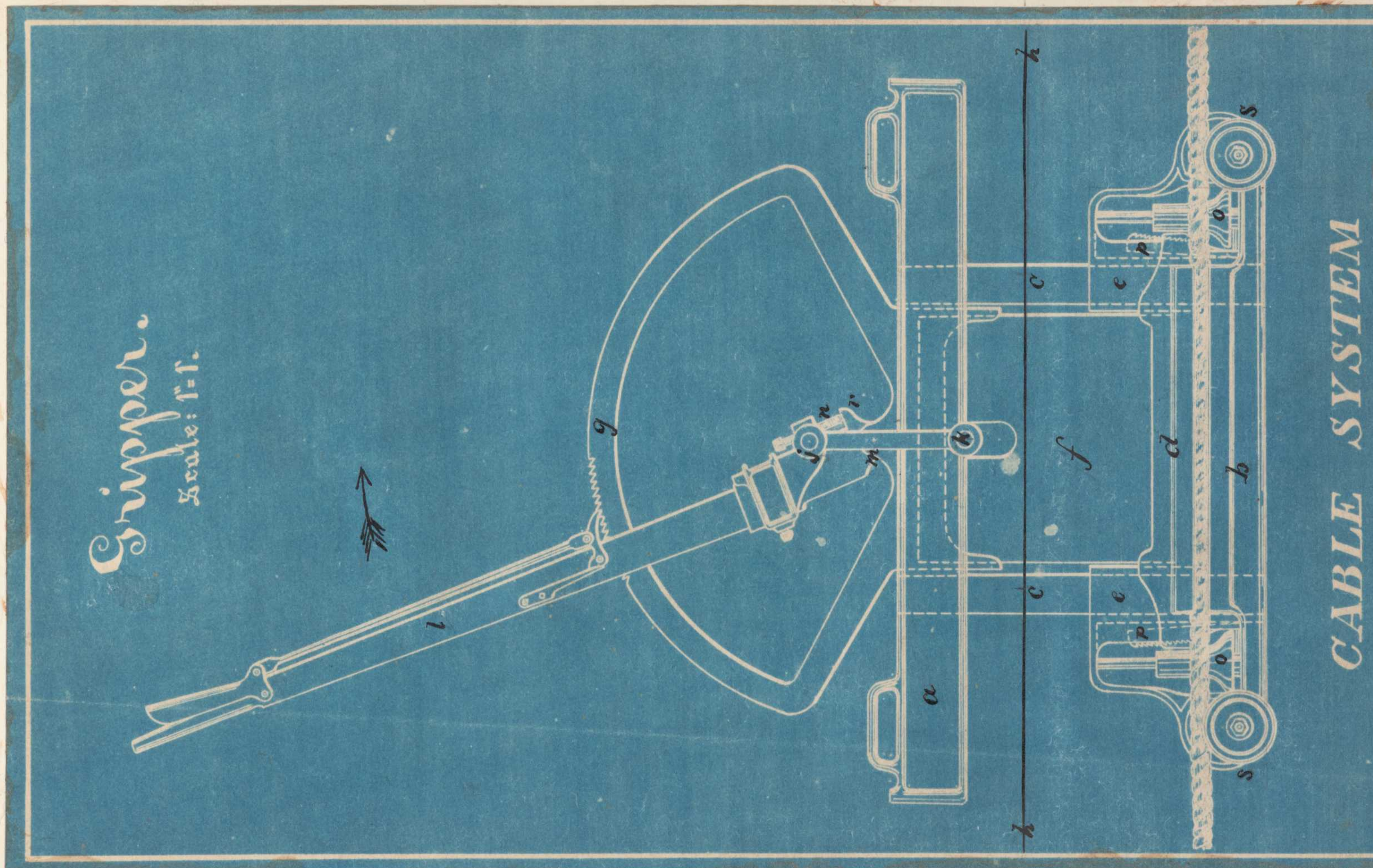


PLATE 18.

CABLE SYSTEM OF THE CHICAGO CITY RAILWAY CO.

C. B. Holmes, ______________ *Pres. & Supt.*

PLAN OF MAIN OPERATING DEPARTMENT—STATE AND TWENTY-FIRST STREETS.

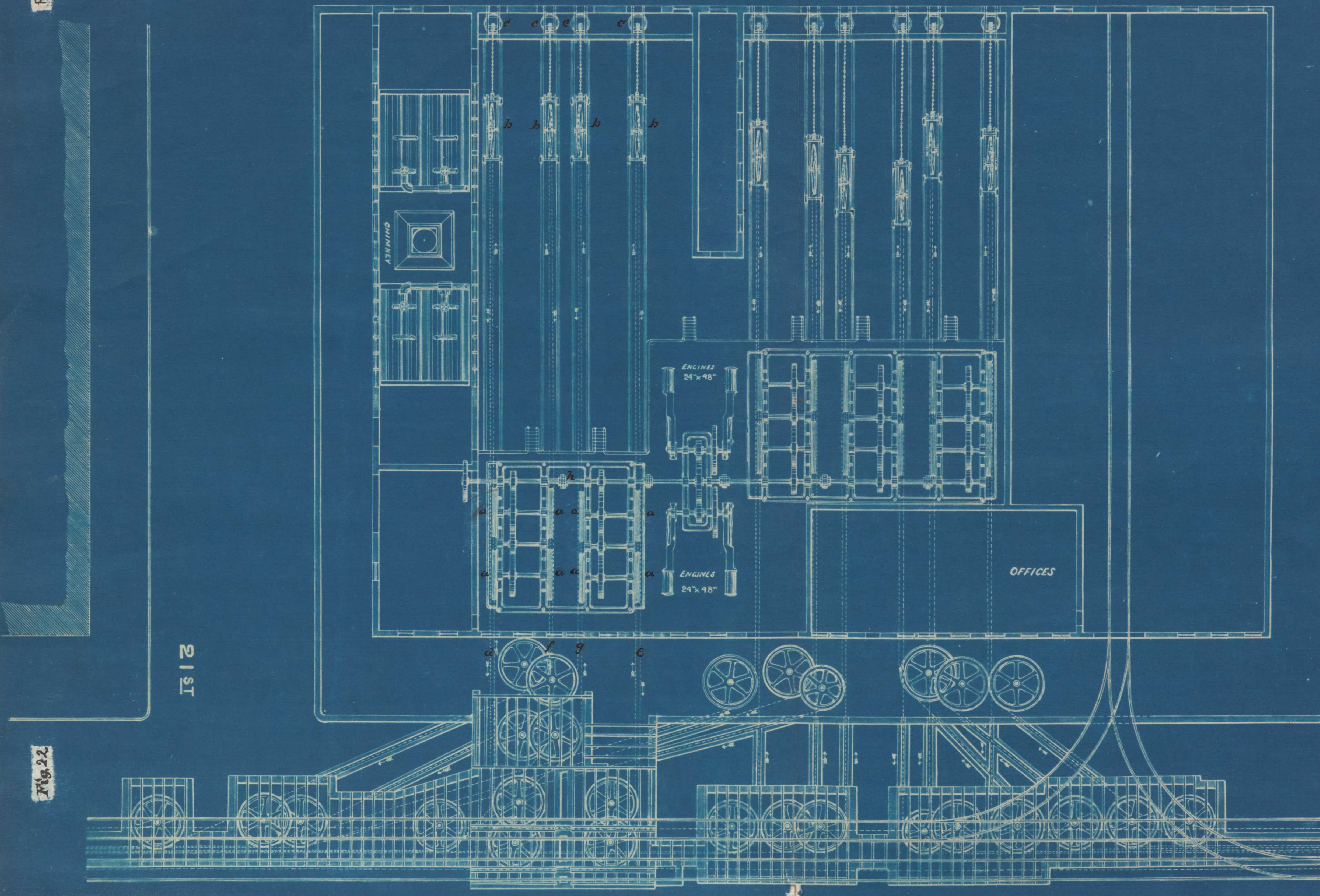


Fig. 22